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INTRODUCTION

Computers to recognize spoken language are on the horizen. Feasibility models and early designs have been constructed at NASA - ERC, Bell Telephone Laboratories and elsewhere. Ultimately, spoken language recognizing computers may find application in a wide range of tasks. The goal of the present research is to investigate some of the factors which affecting the application of such computers to Air Traffic Control.

Perhaps the most critical factor affecting the design of oral language recognizing computers is the number of discrete words which the computer can recognize. Accordingly, the present study is designed to investigate the relationship between the number of words in the computer's vocabulary and the efficiency of the man/machine interface.

Since no such computer is available to us we proceed through simulation. Simulation of men by computers is not unusual. We have reversed the process; students are being trained to respond rapidly and appropriately to statements and questions couched in a synthetic English like computer language.

Questions or statements which are in any way unacceptable are rejected by the "computer" and an error message is transmitted instead.

An air traffic control like game has been constructed.

Subjects acting as controllers will be trained to control approaching and departing aircraft. Each subject will act as his own control - learning first to control aircraft in a purely manual mode (no computer assist) and subsequently with the help of computers with various vocabulary sizes. Our goal is to find how performance on the ATC task varies as a junction of computer vocabulary size.

In the sections that follow our progress on each of the elements of this program is presented.

COMPUTER LANGUAGE MANUAL

LUCY SYSTEM

Linguistic Understandable Computer and memorY

Final Draft - October, 1969

The following is a low redundancy language, based on English lexical items with arbitrary meaning assignments, designed to provide an efficient means for communication with a computer about air-traffic control transactions. Erroneous messages to the computer are returned and must be properly restated.

The computer is programmed to accept and output information as required. Any information stored is automatically updated by means of mathematical models. In addition, information is automatically deleted when an aircraft leaves the control area, or when a sequence number is updated.

The basic design consists of three types of messages, each with its own syntax, employing a vocabulary of 56 words.

Message-Type 1: Statement

A message conveying information to the computer for storage is not preceded by any signal, unlike the other types of messages. It is assumed that each communication from an aircraft will contain one or more data items to be stored in the computer, unless it is a request or question. The items are:

a. type of aircraft
b. identification
c. location
d. altitude

The data items provided by the aircraft are scanned by the controller and restated as a Type 1 message for computer storage. The form of the message is the following:

Formula 1: type of aircraft / IN - OUT / location / altitude
(distance-
direction)

Example: AA FOUR FIVE FOUR IN TWO ZERO SOUTH ALTITUDE THREE FIVE

(Interpretation: AA 454 is inbound, presently 20 miles south of the airport at 3,500 feet.)

Example: SEVEN FOUR NINE NINE R IN POINT A ALTITUDE TWO FIVE

(Interpretation: Aircraft 7499R os at holding point A, inbound, and at an altitude of 2,500 feet.)

ALL ALTITUDES ARE IN HUNDREDS OF FEET. Example: FOUR FIVE is 4,500.

In the formulas, slashes represent divisions between data fields; parenthesis are placed around options. Fields may be omitted by substituting the signal BLANK.

Example: AA FOUR FIVE FOUR IN ONE FIVE SOUTH BLANK

(Interpretation: AA 454 is inbound, now 15 miles south of the airport at the same altitude as before.)

A secondary form of the same type of message is produced by using the RUNWAY option, or SEQUENCE option in the third field.

Formula II: type of aircraft / IN - OUT / (RUNWAY ØØ) (SEQUENCE ØØ)

Example: TWA TWO NINE IN RUNWAY THREE FOUR

(Interpretation: TWA 29 has been assigned to runway 34 for landing.)

Example: MOH NINE ONE IN SEQUENCE FOUR

(Interpretation: MOH 91 has been assigned sequence number 4 for landing.)

Message-Type 2: Questions

A query to the computer is prefixed and followed by the signal Q (pronounced "cue"). Two kinds of questions are available: data about specific aircraft, and data about specific coordinates. In querying the computer about specific aircraft, the controller may ask about its "LOCATION" (altitude, direction, distance or holding point), signalled by the word STATUS: its estimated time of arrival, signalled by the word TIME: its sequence number, signalled by the word SEQUENCE: its assigned runway, signalled by the word RUNWAY.

All these may occur singly or in combination.

Formula III:
Q / type of aircraft / (STATUS) (TIME) (RUNWAY) (SEQUENCE) / Q

Example: Q TWA TWO FIVE STATUS Q

(Interpretation: What is the location of TWA 25?)

Example: Q FOUR TWO C H TIME Q

(Interpretation: What is the estimated time of arrival of aircraft 42 CH?)

Example: Q MOH ONE EIGHT RUNWAY SEQUENCE Q

(Interpretation: What is the runway assignment, and sequence number of aircraft MOH18 ?)

In querying the computer about a group of aircraft, the controller may ask about a holding pattern (all aircraft and altitudes) by the word STATUS: the sequence numbers of the first N inbound or outbound aircraft by the word SEQUENCE: all inbound or outbound aircraft by the word STATE: and the first available open sequence number by the word OPEN.

The second type of query takes the following form:

Formula IV: Q / (STATUS) (SEQUENCE) (STATE) (OPEN) / Q

Example: Q STATUS POINT A Q

(Interpretation: What aircraft are holding at point A?)

Example: Q SEQUENCE IN SEVEN Q

(Interpretation: What inbound aircraft have the first seven sequence numbers?)

Example: Q STATE OUT Q

(Interpretation: Which aircraft are outbound?)

Example: Q OPEN IN Q

(Interpretation: What is the first inbound avaliable sequence number?)

Replies

The answers provided by the computer to the Q-type messages are equally formal. To a query of the first type:

Example: Q TWA FOUR FIVE STATUS Q

The reply takes the following form:

Formula V: type of aircraft / IN - OUT / specifications / END

Example: TWA FOUR FIVE IN TWO SEVEN NORTH WEST ALTITUDE SIX ZERO END

(Interpretation: TWA 45 is inbound, and is now twenty-seven miles north-west of the airport at 6,000 feet.)

To a query of the second type:

Example: Q SEQUENCE IN THREE Q

The reply takes the following form:

Formula VI: specification / IS / type of aircraft / . . . / END

Example: SEQUENCE IN ONE IS TWA FOUR EIGHT SEQUENCE IN TWO IS THREE SEVEN FOUR L G SEQUENCE IN THREE IS BLANK

(Interpretation: Sequence number one inbound is held by TWA 48; sequence number two inbound is held by aircraft 374 LG; sequence number three inbound is blank.)

The same pattern applies to all other possible quires of this second type: items in storage are retrieved and listed, by ascending sequence number, ascending altitude, and the like.

Message-Type 3: Commands

The third kind of message consists of commands to the computer to effect a change in data storage. The signal preceding the message is the word SET.

Formula VII: SET SEQUENCE / IN - OUT

Example: SET SEQUENCE OUT

(Interpretation: Reset all aircraft with outbound sequence numbers lower by one, e. g. 2 becomes 1, 3 becomes 2, etc. The aircraft that has number 1 has any reference to sequence number deleted when another aircraft is assigned the number 1.)

Example: SET SEQUENCE IN

(Interpretation: Reset all inbound sequence numbers lower by one, deleting the lowest sequence numbered aircraft from the computer memory.)

Example: SET TWA FIVE FIVE

(Interpretation: Delete TWA 55 from the computer memory.)

NOTE: In addition to the use of SET, an aircraft is automatically deleted when outbound and beyond the control area.

V O C A B U L A R Y

A-Z (26 items)

0-9 (10 items)

NORTH, SOUTH, EAST, WEST (4 items)

OPEN

IN

OUT

POINT.

RUNWAY

ALTITUDE

BLANK

Q

SET

STATUS

TIME

SEQUENCE

RUNWAY

STATE

IS

END

PRELIMINARY DRAFT

SUBJECT'S INSTRUCTIONS

This experiment is to see how well you can function as an Air Traffic Controller. Your job will be to direct the landing and takeoff of aircraft as safely and efficiently as possible. You may assume that due to poor weather conditions, all aircraft are flying "blind" and are totally dependent on you for flying instructions. These instructions will fall into three basic catagories:

1. Direction: You may denote the direction the plane is to move by either bearings or if desired compass points (8 points only N, NE, E, SE, S, SW, W, NW).

2. Altitude: Allowed altitudes are even multiples of 1000 ft. or 500 ft. As ground is considered at zero feet, and obstructions do exist, 1000 feet is the minimal allowable altitude. Examples of altitudes are:

1000
1500
2000
2500
3000
3500
etc.

6,000 is maximum altitude that you may expect to encounter. Aircraft may therefore fly between 1,000 and 6,000 ft. but you may not request aircraft to fly above the altitude reported during initial contact for landing. It is your objective to LAND aircraft, not climb to a higher altitude.

3. Speed: There are four general types of aircraft, 2 private and 2 commercial. Each has a specific cruising speed and corresponds to

a specific aircraft type as follows:

COMMERCIAL - 480 mph - Jet
- 360 mph - Prop. Driven

PRIVATE - 240 mph - Twin Engine Propeller
- 120 mph - Single Engine

These speeds are the only speeds available.

Separation

Aircraft must be separated by a minimum of 500 ft. in ALL DIRECTIONS.

Maneuvering

In any case of maneuvering, aircraft cannot do things immediately. You must remember that any corrective action must be taken early enough to allow the aircraft to change its direction or altitude as follows:

Altitude - all aircraft climb or decend at 2000 ft/min.

Direction - all aircraft can turn 360° in one minute or 1°/sec.

LANDING AND TAKEOFF PROCEDURES:

1. Landing.

An aircraft that is landing will call you telling you its identification numbers, its altitude, and position. All aircraft are headed to the airport at the center of the map. Until the plane is landed, you must decide where the plane must go. As mentioned previously, only you have the authority to permit aircraft to land. All pilots are "Blind" and therefore must land electronically. The map has three red keys. At the end of each key is the start of an electronic beam where each plane must be sent in order to land. In order for a plane to land you must direct it to the end of this key in the general direction of the runways shown by the red lines at the center of the map. As this electronic landing system only works between 1500 and 3000 feet, all aircraft must enter this position within these altitudes.

Should it become necessary to delay planes from landing, three "Holding patterns" are available. These are areas of special electronic ground equipment that permit aircraft to circle over at specific altitudes. The available altitudes for each of the "Holding patterns" denoted by red circles are shown on the map.

2. Takeoff

Aircraft that wish to take-off will tell you in what direction they wish to go. You must supply information regarding proper altitude, and when a runway is clear give permission for the plane to take- off.

AIRPORT PROCEDURES

The airport consists of two intersection runways. Aircraft may use both runways as long as the runway is clear and there is no conflict between runway usage. The numbers shown at the end of each runway are their identification. You must tell the aircraft which runway to use depending upon wind conditions as shown on the runway display. Both landing and takeoffs use the runway in the same direction. Only in emergency cases should the opposite ends of the runway be used.

Before you start this experiment, the supervisor will proceed with a sample task to show you what is to be done. If you have any questions, please ask them now. Once you start the experiment, you may not ask any questions.

PRELIMINARY DRAFT

PILOTS INSTRUCTIONS NOT FOR DISTRIBUTION

Your job will be to act as pilots for four aircraft. It is imperative that you remember which planes are under your control, and when to move them as described below.

The map you will use contains a polar coordinate system blocked off into 1/2 by 1/2 mile squares (approximately). Each plane occupies one of these blocks and may move only between blocks. There are four different speed aircraft types which have speeds of:

120 mph
240 mph
360 mph
480 mph

As each plane is moved every 15 secs when a beep is given, the planes will be moved 1 block for each 120 mph. Therefor:

120 mph moves 1 block
240 mph moves 2 blocks
360 mph moves 3 blocks
480 mph moves 4 blocks

To make things easier, the high pitch tone moves odd numbered planes, and the double low pitch tone moves even number planes. As shown by the simulated plane, the last number of its identification determines even/odd.

Some other facts to note about the simulated planes are:

The arrow is to be the direction the plane is moving.

The A B C D are the speeds, A slow: D, fast. Only one is marked for the speed.

The range of numbers is the altitude of the plane which you must mark. To simplify moves, a PLANE MAY ONLY CHANGE ALTITUDE 500' PER MOVE

(BEEP).

When you are told to change aircraft direction, the same number of blocks will be covered, but going in the desired direction UP TO 90^{o} PER MOVE (BEEP). Any shorter change in direction still requires one beep, i.e. 0 to 90^{o}, 91 to 180^{o}requires two moves.

A demonstration of the above will now be given.

Now that you are familiar with the planes operation, the two piloting jobs will be discussed. These are: landing, takeoff.

LANDING

The tape recorder will tell you when to introduce a plane, giving PLANE NO., LOCATION, ALTITUDE. As all planes are landing, point them to the center (airport) and call the controller. (How to speak will be given later.)

It is now up to you to move the planes at the proper time (odd/even). If you are cleared for landing, you must be at a"KEY" between 1,500 to 3,000 feet to say that "PLANE _____ ON ELECTRONIC LANDING BEAM." Once you have landed, according to moves, you will inform controller that you have landed. THEN RETURN PLANE TO PROPER PARKING POSITION.

During your landing, you may be told to hold at one of the three places marked on the map at a specific altitude. Move the plane as per above instructions until you are at the center of the point desired. Make sure your altitude is marked, and leave the plane there.

TAKEOFF

Again you must call the controller, furnishing the information given on the tape. Then just follow controllers instructions.

NOTE: IN ADDITION TO THE TAPE, YOU WILL HAVE A SCRIPT.

You will also be monitored by the 'computer' to ensure that the planes are being moved. In addition, YOU MUST PLACE A RED MARKER DOT ON YOUR PLANE IF THE "COMPUTER" INDICATES, AND REMOVE THE DOT WHEN INDICATED. Do not regard what the computer tells to the controller, as the conversation does not concern you. The speakers near you give instructions from the tape and controller. Your mikes are connected to the controllers speaker.

The last point is your area of responsibility. YOU WILL ONLY CONTROL YOUR DESIGNATED PLANES AND NO ONE ELSES. YOU WILL BE ASSIGNED A COLOR CODE. THE INSTRUCTIONS WILL ALL BE PREFACED BY A COLOR CODE.

In case of aircraft overlapping, the chief pilot will take over the job of telling you what to do.

GOOD-LUCK.

PRELIMINARY DRAFT

NOT FOR DISTRIBUTION

GRADING OF SUBJECTS

1. LANDINGS

Grading will be the variation from expected arrival time based on the minimum amount of time required for a plane to land following a straight course.

2 TAKEOFFS

Grading will be the delay from the time the plane indicates it is ready to takeoff.

3. NEAR-MISSES

Aircraft that are within 1000' vertically in the same block or adjacent blocks.

4. COLLISIONS

Aircraft that are within 500' vertically and in the same block.
Any penatration of a holding pattern within 500'.

PRELIMIANARY DRAFT

MATERIALS USED

Maps

Two special area maps were constructed for the controller and pilots. Both showed the simulated airport with distances and holding patterns. As this is only a simulation, all aircraft are moved in fixed increments. Only the pilots use a larger, incremental spaced map composed of approximate squares corresponding to the minimum distance an aircraft may travel during the 15 second period. The pilots then simply move their aircraft the proper number of blocks every 15 seconds. As all blocks are approximately 1/2 x 1/2 mile, then the aircraft move:

120 mph - 1 bloc (1/2 m/15 seconds)
240 mph - 2 blocks (1m/15 seconds)
360 mph - 3 blocks (1 1/2 m/15 seconds)
480 mph - 4 blocks (2 m/15 seconds)

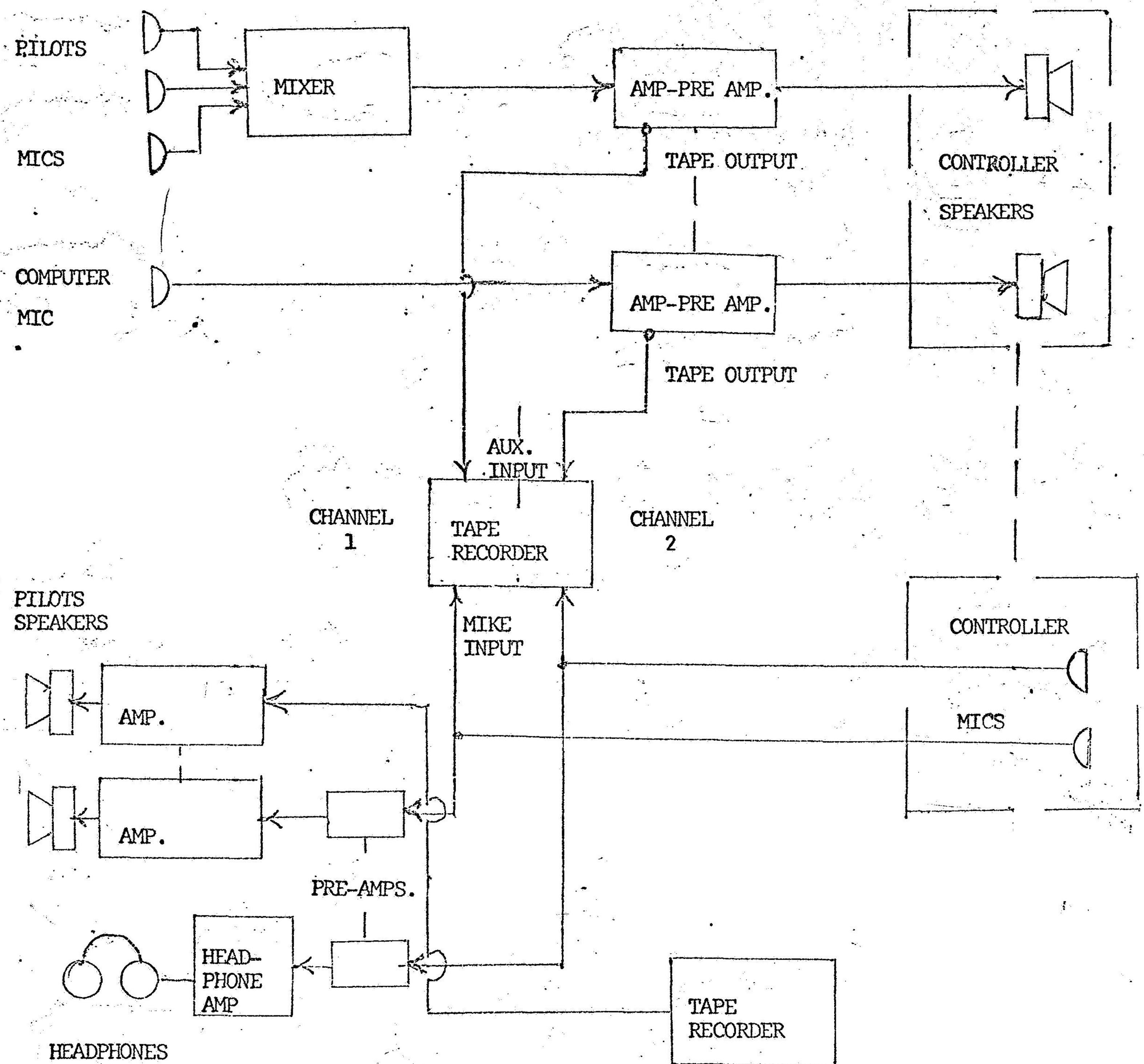
When the computer is in operation, the same pilot map will be used with the pilots marking aircraft in the computer memory. The computer then will scan the map to determine the information required.

All instructions will be given to the controllers and pilots by use of a pre-recorded tape to eliminate any variation. In addition both controllers and pilots will have a written set of instructions for reference. Two sets of conversations will be recorded simultaneously using a stero tape recorder. These conversations are controller - computer and controller-pilots. This will permit a more rapid evaluation and grading of the experiment.

Airplanes:

The "airplanes" used in this experiment were constructed from transparent acetate .030 Millimeter in thickness. They are approximately two and one-half inches long and one-half inch wide. The pointed end of the plane indicates the direction of the plane is moving. On the left side edge a range of numbers from one through six and an adjustable slider have been placed to indicate altitude.

There are four different speed aircraft available. The A B C D marked on the right side of the plane indicate the particular speed of that plane. Only one of these letters is marked. In addition, each plane has an identification number and space enough for a red disc marker to be placed should the activities of the plane be reported to the computer.



ELECTRONIC DIAGRAM

Provides for separate recording of controller-computer and controller-pilots conversation.